SA53A-09: Results from a new approach to meso-scale driving of the I-T system: HIME

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Xing Meng[1], Olga Verkhoglyadova[1],
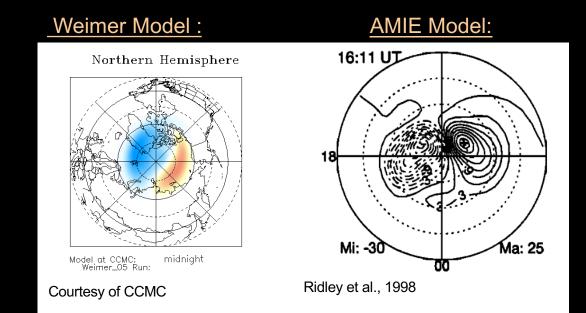Roger Varney[2], Ashton Reimer[2], Josh Semeter[3]

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Role of Meso-scale Electric Fields in I-T Energy Budget

$$Q_{JH} = \sigma_P [\boldsymbol{E} + u_n \times \boldsymbol{B}]^2$$

- Traditionally, conductivity and electric fields are estimated through empirical models.

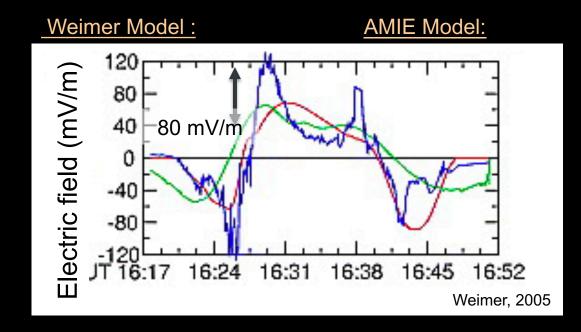- Current models can not resolve the meso-scale structures but significant work is ongoing[*].

Weimer Model :

Courtesy of CCMC

AMIE Model:

Ridley et al., 1998

*[Codrescu et al. 2008; Deng et al. 2009; Matsuo & Richmond 2008; Zhu et al. 2018].

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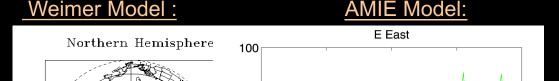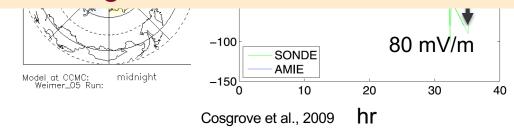
Weimer Model :   AMIE Model:

80 mV/m

Weimer, 2005

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Weimer Model :   AMIE Model:

Meso-scale electric fields (<15 minutes, 150-500 km) introduce as much energy as the large-scale structures.

- Current models can not resolve the meso-scale structures but significant work is ongoing*.

Cosgrove et al., 2009
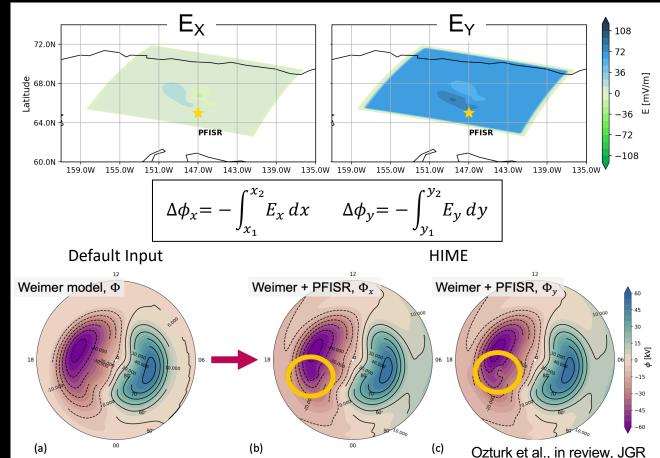
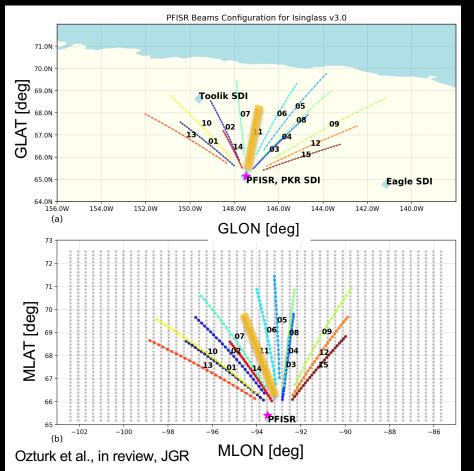*[Codrescu et al. 2008; Deng et al. 2009; Matsuo & Richmond 2008; Zhu et al. 2018].

High-latitude Input for Meso-scale Electrodynamics: HIME

- Nicolls et al. (2014) technique estimates F-region electric fields on a 2-D grid from the PFISR V_{LOS} measurements.

- These estimates can be merged with a <u>global empirical potential model</u> to drive global I-T models and investigate the role of meso-scale electric fields.

$$\Delta\phi_x = -\int_{x_1}^{x_2} E_x \, dx \qquad \Delta\phi_y = -\int_{y_1}^{y_2} E_y \, dy$$

Ozturk et al., in review, JGR

Running a global I-T model with HIME

PFISR Beams Configuration for Isinglass v3.0

(a)

Ozturk et al., in review, JGR

(b)

Modelling:
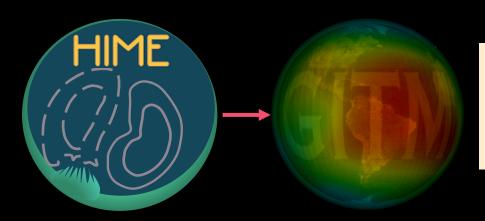
- PFISR aiding the ISINGLASS experiment with 15 beams operating [Clayton et al., 2019a, 2019b, JGR.]

- The electric field estimates:

  – Temporal resolution [66 seconds]

  – Spatial resolution [0.05° in latitude and 0.3° in longitude, ~10 km]

  – Down-sampled to 0.75°x0.75°: 35x80 km

Validation:

- PFISR plasma measurements along Beams

- Three SDI (Scanning Doppler Imagers) measurements for neutral wind

Running a global I-T model with HIME
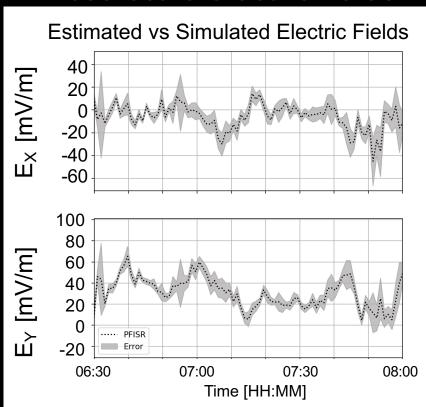
HIME is an add-on framework and does not require major source code modification.
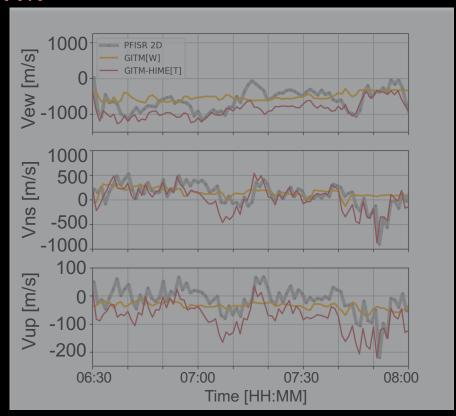
Global Ionosphere -Thermosphere Model (GITM)

- 3D, altitude based non-uniform grid, assumes non-hydrostatic solution
- High-latitude input: Electric potential and particle precipitation
- Output: Plasma and neutral density, temperature, ion and electron velocity, neutral winds
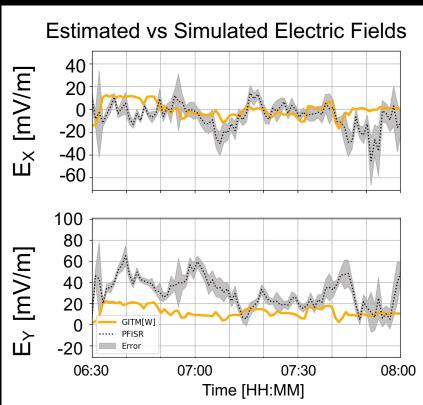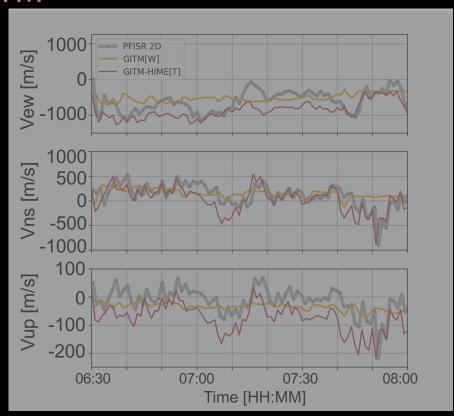
Ridley, Deng and Toth, JASTP, 2006
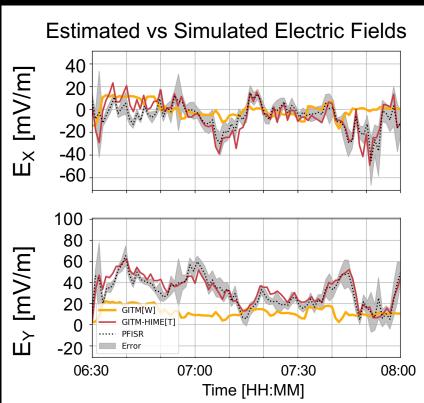
Meso-scale electric fields in GITM

Estimated vs Simulated Electric Fields

Electric field estimates from PFISR successfully incorporated.

Estimates of velocity improved for all three components. jpl.nasa.gov

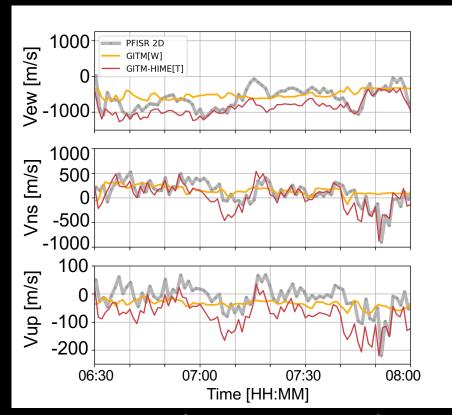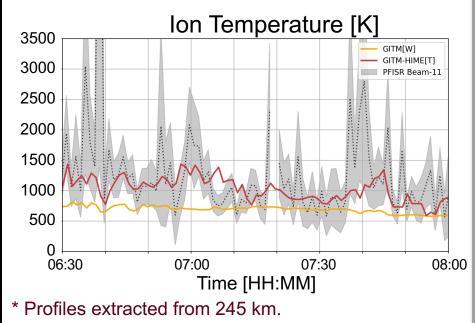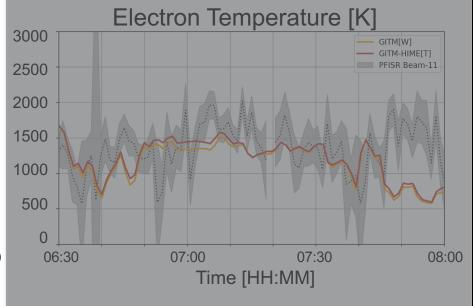# Meso-scale electric fields in GITM

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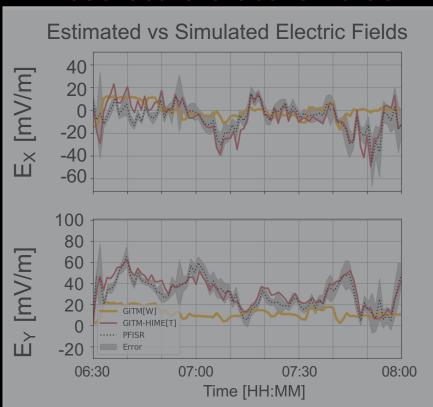
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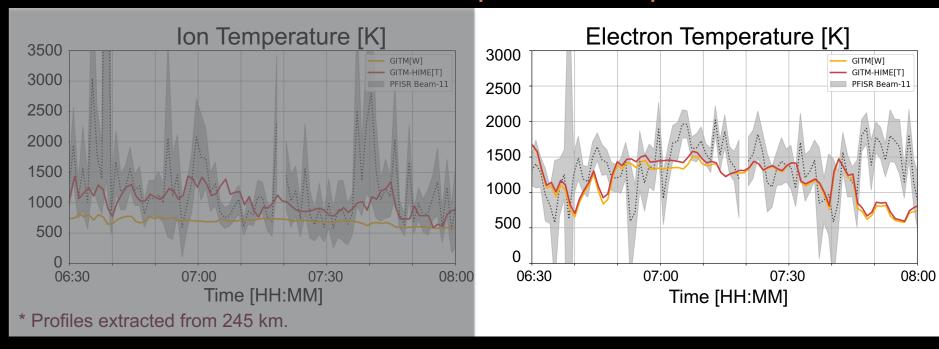
Modeled ion and electron temperature response

Ion Temperature [K]

Electron Temperature [K]

* Profiles extracted from 245 km.
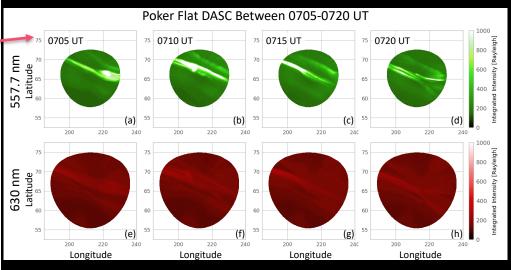
Modeled ion temperature <u>captures variability</u> better when meso-scale electric fields are used.

Modeled electron temperature <u>captures the amplitude</u> but does <u>not reproduce the short-lived peaks</u>.
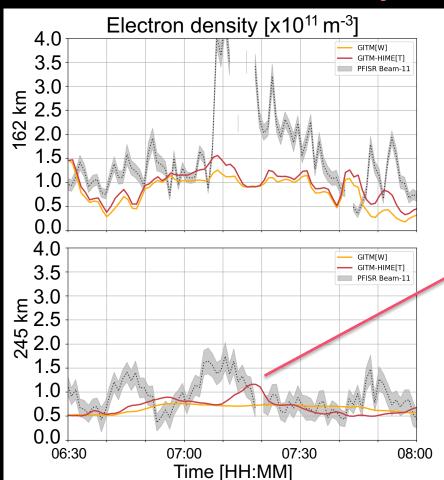
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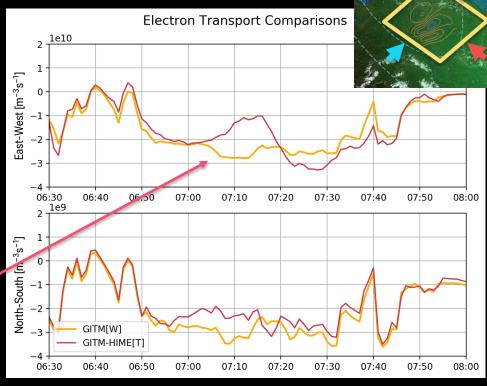
Modeled electron density response

Electron density [x10^{11} m^{-3}]

Poker Flat DASC Between 0705-0720 UT

Poker Flat DASC, collocated with PFISR, shows bright dynamic aurora over the same region.
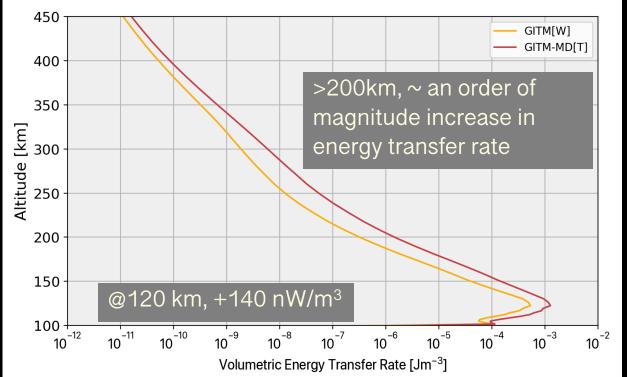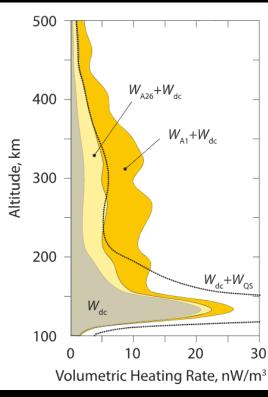
Modeled electron density response

Increase in simulated electron density likely due decreased westward transport mechanism.

Energy transfer rate with meso-scale electric fields

>200km, ~ an order of magnitude increase in energy transfer rate

@120 km, +140 nW/m^3

Lotko and Zhang, 2019

The deposited energy increases locally in HIME-driven simulation compared to Weimer-driven simulation above 110 km.

Effects of Meso-scale electric fields in the I-T system

The HIME driven simulations showed that meso-scale electric fields can lead to:

- Variations in the electron density due to transport.

- Collisional and frictional heating of the plasma and neutrals.

- Increased volumetric heating along the vertical profiles.

Ongoing and future work on HIME:

- A self-consistent treatment of particle precipitation is necessary to fully understand the effects of meso-scale structures.

- Further case studies are necessary to assess the performance of HIME.

Thank you.

Acknowledgements

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